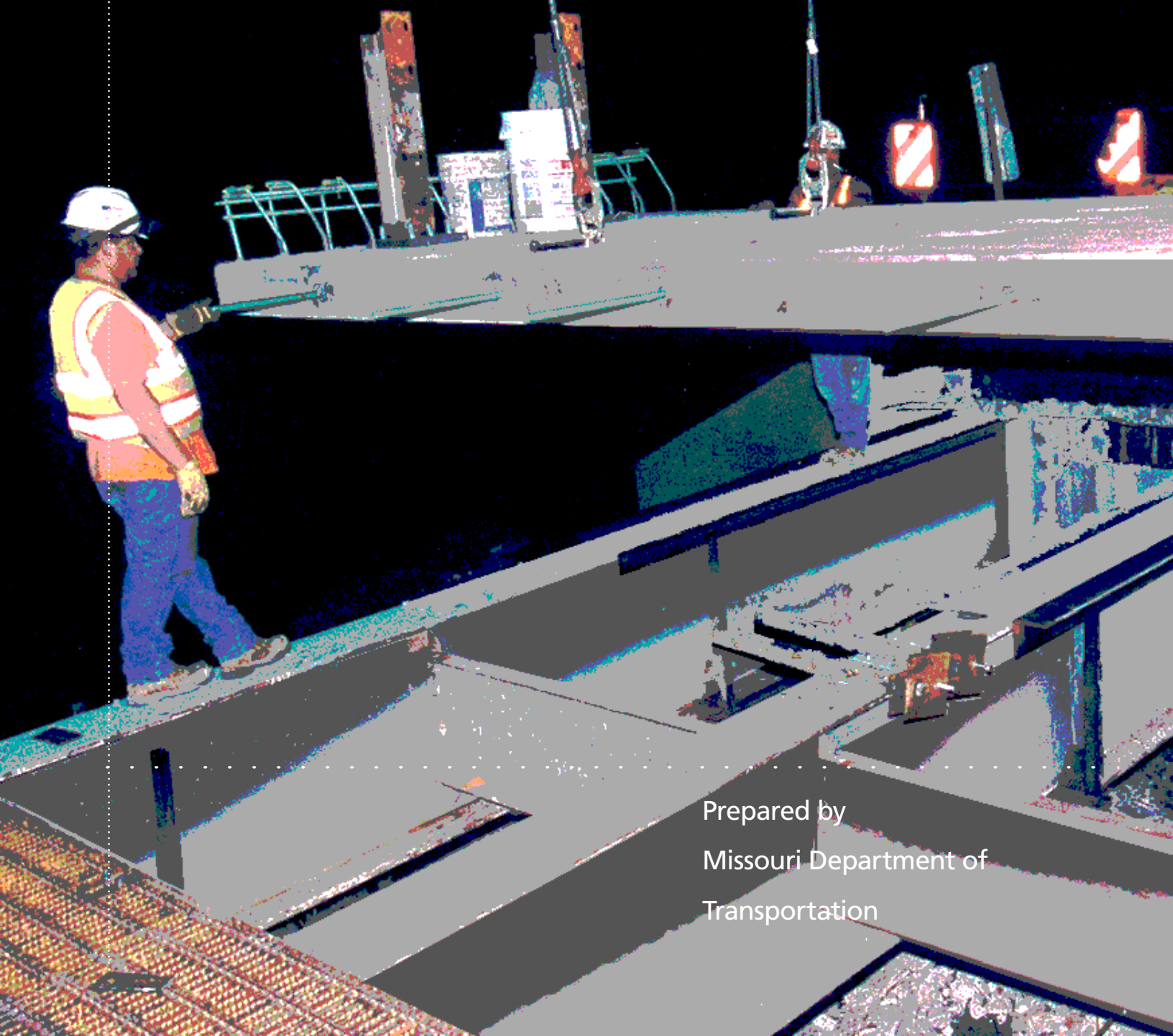


Deck Replacement with Precast Concrete Segments



Prepared by
Missouri Department of
Transportation

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. OR06-003	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Deck Replacement with Precast Reinforced Concrete Segments		5. Report Date August 19, 2005	
		6. Performing Organization Code RI04-027	
7. Author(s) John "JD" Wenzlick, P.E.		8. Performing Organization Report No.	
9. Performing Organization Name and Address Missouri Department of Transportation Research, Development and Technology P. O. Box 270-Jefferson City, MO 65102		10. Work Unit No.	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Missouri Department of Transportation Research, Development and Technology P. O. Box 270-Jefferson City, MO 65102		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes The investigation was conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.			
16. Abstract <p>The deck to be replaced in this project was on the Nemo Bridge, built in 1960 by the US Army Corps of Engineers over Pomme De Terre Lake. This 1698 ft. long steel bridge had wide flange girders with a 7 in. thick composite reinforced concrete deck only 22 ft. wide.</p> <p>HNTB Company, the design consultants, had originally designed the deck to be built by conventional methods one lane width at a time, which would have taken 2 years and required one-way traffic on the bridge during the whole construction. The narrow lane would not allow emergency vehicles or school busses to cross. Closing the bridge would have caused a 30-mile detour. Bridge Maintenance Engineer, David O'Connor, suggested using full thickness pre-fabricated deck panels to speed up the construction of the Nemo Bridge. MoDOT received favorable response to this idea internally and also at an on-site public hearing. The local residents and business owners were very supportive and excited about the idea of less traffic disruption, especially on busy summer weekends when tourists, campers and fisherman are visiting.</p> <p>HNTB then started redesigning the bridge plans. It was decided to replace the deck by only closing the bridge on Sunday through Thursday nights from 7PM to 7AM between the Memorial Day weekend and the Labor Day weekend. A precast deck system, using 10 ft. long precast sections with the barrier attached, to allow overnight replacement of at least 30 feet of bridge deck per night. To offset some of the costs of the prefabricated deck panels \$160,000 of federal Innovative Bridge Research and Construction (IBRC) funds were used.</p> <p>The contract went smoother than expected because of the excellent work of the design group and innovative practices of the contractor. The contractor, CC&G, had to cast 162 precast sections and had only one 10-foot panel rejected. Because of forming on a long casting bed by continuous spans, the longitudinal alignment of the in place sections was almost perfect. CC&G set as many as eight sections, 80 feet of new deck, in one night. They had no problem in setting the whole deck before Labor Day 2004 saving an entire year of construction and inconvenience to the public.</p>			
17. Key Words Precast concrete, segmental, deck replacement, bridge decks		18. Distribution Statement No restrictions. This document is available to the public through National Technical Information Center, Springfield, Virginia 22161	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 20	22. Price

FINAL REPORT

RI04-027

**Deck Replacement with Precast Reinforced
Concrete Segments**

Prepared for the

Missouri Department of Transportation
Organizational Results

By

John “JD” Wenzlick, P.E.
Missouri Department of Transportation
Organizational Results

August 2005

The opinions, findings, and conclusions expressed in this publication are those of the principal investigators and the Missouri Department of Transportation; Research, Development and Technology. They are not necessarily those of the U.S. Department of Transportation, Federal Highway Administration. This report does not constitute a standard or regulation.

Executive Summary

The deck to be replaced in this project was on Bridge No. A0894, known as the Nemo Bridge. It was built in 1960 by the US Army Corps of Engineers over Pomme De Terre Lake. This 1698 ft. long steel bridge had wide flange girders with a 7 in. thick composite reinforced concrete deck only 22 ft. wide. A preliminary survey showed that over 60% of the deck concrete was delaminated at the rebar level and that the deck needed replaced.

HNTB Company, the rehabilitation design consultants, had originally designed the deck to be built by conventional methods one lane width at a time, which would have taken 2 years and required one-way traffic on the bridge during the whole construction. The narrow lane would not allow emergency vehicles or school busses to cross. Closing the bridge would have caused a 30-mile detour.

The Bridge Maintenance Engineer in MoDOT's Springfield District, David O'Connor, came back from a National Prefabricated Bridge Elements Conference in St. Louis and suggested to the project manager using full thickness pre-fabricated deck panels to speed up the construction of the Nemo Bridge. MoDOT received favorable response to this idea internally and also at an on-site public hearing. The local residents and business owners were very supportive and excited about the idea of less traffic disruption, especially on busy summer weekends when tourists, campers and fisherman are visiting.

HNTB then started redesigning the bridge plans, even though they were about 90% complete using the cast-in-place or CIP method. It was decided to replace the deck by only closing the bridge on Sunday through Thursday nights from 7PM to 7AM between the Memorial Day weekend and the Labor Day weekend. HNTB and MoDOT thus designed a precast deck system, using 10 ft. long precast sections with the barrier attached, to allow overnight replacement of at least 30 feet of bridge deck per night. The project was let on March 19, 2004 and awarded to Columbia Curb and Gutter Co. (CC&G) for \$5.5 million. The project also included replacing expansion joints, re-painting of the entire superstructure and replacement of the abutment backwalls. To offset some of the costs of the prefabricated deck panels \$160,000 of federal Innovative Bridge Research and Construction (IBRC) funds were used.

The contract all in all went smoother than expected because of the excellent work of the design group and innovative practices of the contractor. The contractor had to cast 162 precast sections and had only one 10-foot panel rejected. Because of forming on a long casting bed by continuous spans, the longitudinal alignment of the in place sections was almost perfect. CC&G set as many as eight sections, 80 feet of new deck, in one night. They had no problem in setting the whole deck before Labor Day 2004 saving an entire year of construction and inconvenience to the public. MoDOT will benefit by replacing an old 7" thick badly deteriorated deck with a new 9 ½" thick reinforced concrete deck, including a 1 ½" silica fume overlay, with epoxy steel that will make the bridge even stronger than originally designed and with a minimum of inconvenience to the summer tourism business. Also with the rehabilitation and painting of the steel and new expansion joints it will be like a brand new bridge and should add another 50 years to its life.

Table of Contents

List of Figures	ii
Introduction.....	1
Present Conditions	1
Results and Discussion (Evaluation)	3
Precasting the Deck Panels	3
Removing the Old Deck.....	6
Setting the Deck Panels	6
Placing the Barrier and Silica Fume Concrete Overlay	10
Deck Replacement: Summary and Timeline	11
Conclusions and Recommendations	12

Appendix A - Research Work Plan

List of Figures

Figure 1: A plan and cross-section of the deck.....	2
Figure 2: Casting bed – laying out forms for 10” sections.	3
Figure 3: Trial match-cast sections showing keyways on both sides of panels.....	4
Figure 4: Rebar cage (w PT Tubes and foam blockouts for shear studs, etc.)	5
Figure 5: Jacking match-cast panels apart	5
Figure 6: Lifting completed panel from casting bed.....	5
Figure 7: Removing first section of old concrete deck	6
Figure 8: Background – Jackhammering around shear Studs.....	6
Figure 9: Installing temporary deck panels.....	7
Figure10: (In background) Temporary guardrail transition existing guardrail.....	7
Figure 11: Setting the first precast panel	7
Figure 12: Welding new shear studs to steel girder.....	8
Figure 13: Post tensioning sections together.	8
Figure 14: Pouring grout into 2nd of 4 blockout	8
Figure 15: Removing 2x4 after grout set in about 2 hours.	8
Figure 16: getting ready for placement of concrete between precast sections and around new finger expansion joint	9
Figure 17: Placing barrier curb by slipform method.....	10
Figure 18: Uncovering the last of silica fume overlay placements.....	11

Hickory County, Rte. 64, Pomme de Terre Lake Bridge Job No. J8S9654

Introduction

Nestled in southern Hickory County, deep in the Missouri Ozarks, lies the beautiful Pomme de Terre Lake. Completed in 1961 by the Corps of Engineers, the lake was designed to be part of a comprehensive flood control plan for the Osage River Basin. But it developed into much more: boating, swimming, fishing, hunting, and camping. Pomme de Terre has become an outdoor recreation paradise for Missourians and visitors alike.

Construction of the Route 64 Bridge, over the Lindley Creek arm of the Lake near Nemo, Missouri, was completed in 1960. The bridge, sometimes referred to as the Nemo Bridge, is a major artery for access to the local marinas and businesses, which cater to visitors year-round. Approximately 2300 vehicles cross the bridge every day.

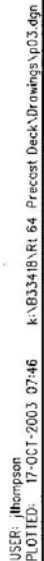
Present Conditions

Eventually, normal deterioration took its toll on the bridge deck, compelling MoDOT to take action. However, the project team was faced with several challenges. The 1684ft. length and the narrow 22ft. width would complicate traffic handling during construction. Weight and lane width restrictions would not allow fire trucks, ambulances, school buses and large recreational vehicles to use the bridge during replacement of the deck. The shortest state route detour was approximately 31 miles in length. The anticipated length of construction of the traditional cast in place bridge deck replacement was two years. The local communities and the surrounding area depend heavily on tourism and the public was very concerned about the length of time their lives and businesses would be disrupted.

District 8 Bridge Maintenance Engineer Dave O'Conner had a different idea. Dave had recently attended a conference and seen a presentation about precast panels for bridge deck replacement.^[1] The project team saw merit in further analysis and investigation into this method in order to speed-up the bridge deck replacement. With the efforts of MoDOT District, Bridge Division staff and its consultant HNTB Corporation of Kansas City, MO the plan moved forward. Even though HNTB had the plans about ninety percent completed they changed the plans to make the deck in precast segments that could be placed over night.

In addition to replacing the deck and all six expansion joints, all of the steel superstructure would be cleaned and repainted, five sets of cantilever bridge girder bearings would be retrofitted, both bridge abutments would be modified and new concrete bridge approach pavements would be installed. It ended up being a \$ 5.5 million job.

1



Results and Discussion (Evaluation)

Precasting the Deck Panels

The contract called for the casting of 10 ft. long sections of the new 27 ft. wide bridge deck with new barrier curbs attached. (*A plan and cross-section of the deck is shown in Figure 1.*) In order to reduce the weight to about 27,000 lbs. each, the contractor, Columbia Curb & Gutter (CC&G) requested pouring the sections without the barrier and later pouring the barrier curb in place as would be done with normal deck construction.

A casting bed 29 ft. wide by 360 ft. long was built on a nearby abandoned quarry just south of the project. Unlike building a regular bridge deck in place where long lengths can be readied for pouring the concrete, this job required 164 individual 10 ft. panels. For panel construction, jigs were made to help place the two layers of reinforcing steel. Then 8 tubes had to be cast into the concrete to hold the PT (post –tensioning) bars that would secure the panels together. Foam block outs were needed to create pockets where shear studs would connect the panels to the structural steel girders. Pockets were also needed around the ends of the PT bars to allow for tensioning after the panels were set. Later the pockets and blockouts would be filled with grout. (*See Figure 3.*)



Figure 2: Casting bed – laying out forms for 10 ft. sections.

The concrete for the precast slab panels had to meet the requirements for Missouri Class B1 concrete and have a minimum compressive strength of 4,000 psi.

A process called “match casting” was used. After the first panel was poured the forms were removed from the edge that would butt up to the next panel. The adjoining edge had the concrete for the second panel poured against the keyway that was originally formed in the first panel, so that the pieces would fit perfectly. The joint between the two panels had a release agent applied to it so when the concrete cured they could be separated. Each adjacent panel was formed in the same way until the pieces for that continuous span were complete.



Figure 3: Trial match-cast sections showing keyways on both sides of panels. One side against forms and one side against concrete.

To get the panels apart on the casting bed two hydraulic jacks were used to push against the pipes stuck in the PT block outs of the opposing panel. The panels were boomed off the casting bed and stored until needed at the project site. This casting practice was done five times for each continuous section of bridge, which ranged from 270 ft. long to 350 ft. The bridge's new deck would consist of 4.4 million pounds of precast concrete panels.



Figure 4: Rebar cage (w PT Tubes and foam blockouts for shear studs, etc.) had to be placed for each 10ft. section before placing concrete. Note this panel is being match cast in between two previously cast panels.



Figure 5: Jacking match-cast panels apart using square steel posts set in blockouts on each side of joint with release agent applied to it



Figure 6: Lifting completed panel from casting bed. Note: keyways showing on edge of opposite panel.

Removing the Old Deck

The old deck was held in place by steel shear studs welded to the top of the I-girders. The concrete was poured over the rebar and the shear studs, which connected the deck to the girders. This design is called composite construction, which helps the deck work with the I-girder superstructure so that the bridge can hold more weight. These studs had to be located and the concrete around them removed. Large concrete saws were also used to cut through the 7-inch thick deck and the curbs to get them in moveable sections. Then a crane would lift out the old deck. (A crane located on the road was used to set the first few panels near the south abutment. After the first few panels, barges in the lake were used to hold the crane, store the removed old deck, and hold the new precast panels. The crane placed the remainder the deck panels from the barge in the lake.) The tops of the girders were cleaned off and the old shear studs removed. Finally fast drying epoxy paint was applied to the tops of the top flange of the existing steel girders.



Figure 7: Removing first section of old concrete deck.



Figure 8: Background – Jackhammering around shear studs to loosen old deck Foreground – Sawing off steel shear studs after old concrete deck removed.

Setting the Deck Panels

To speed up the setting the new deck panels, CC&G built 6 temporary 10ft. bridge spans using small steel I-girders and open steel grate deck to replace the decking removed. They were built to match the 27 ft. width of the new deck panels so the only width transition was from the temporary deck to the existing deck. Pieces were put in manually every night to make a smooth transition from the preinstalled guardrail on the temporary deck to the old guardrail.

The crown of the roadway was formed into the concrete deck panels on the casting bed. When the panels were placed on the four girders, the height or (haunches) over the girders had to be set and the difference filled in with fast setting high strength grout. The panels were set to grade by using jacks that CC&G fabricated. The jacks could be raised or lowered against steel channels, which also served as the forms for the haunches.



Figure 9: Installing temporary deck panels.



Figure 10: (In background) Temporary guardrail transition to existing guardrail.



Figure 11: Setting the first precast panel, Note: Workers under bridge are adjusting jacks for the haunch forms to match the crown cast into the bottom of the deck and bring to proper grade before filled with fast setting grout. Note: Temporary steel deck panel in place in foreground.

The top of the panels had been textured, when cast, with transverse tining to provide a skid resistant riding surface and later on to provide a good bond when the 1 ½" silica fume overlay was placed.

After the panels were set, new shear studs were welded on the top of the girders through the block outs left when casting the panels. Then either 2 or 3 of the new panels were tied together with the PT (post –tensioning) bars. There are 8 PT bars across the width of each panel that needed to be tensioned to 90,000 lbs per bar. Slow setting epoxy concrete glue was used on each matched face of the concrete deck panel before the bars were post tensioned to seal the joints.

The bars were tensioned two at a time using special hydraulic jacks until all were tensioned. Two jacks were used to tension the bars to keep tension equal across the face of the concrete sections.



Figure 12: Welding new shear studs to steel girder through blockout.



Figure 13: Post tensioning sections together. (Note: only one of two rods being tensioned to 90,000 lbs. at same time is shown)

Last, the haunches were grouted through the shear connector pockets each night after the panels had been post tensioned. A special packaged fast setting grout mix was combined with ½" sized aggregate to form the flowable grout. The grout also was used to fill the shear connector pockets and the block outs around the PT bars. The grout was required to reach 4,000-psi strength. The grout set up within a couple of hours so that the deck could be open to traffic at 7:00am the next morning.

After each span of bridge deck was installed the contractor came back and filled the 8 tubes which hold the PT bars with special packaged grout mix, to keep any water out of the tubes and protect the PT bars from corrosion.

The contractor re-used the old posts and channel rails as a temporary guardrail from the new deck panels to original guardrail. He also added a bottom rail to protect the rebar cast into the panels for the new concrete barrier curb.



Figure 14: Pouring grout into 2nd of 4 blockout holes per girder line in precast panel.



Figure 15: Removing 2x4 used to form end of haunch after grout set in about 2 hours.

After all the deck panels were set in place, there were closure pours needed between the continuous spans at the piers. These concrete pours were done on the bridge where expansion joints were being replaced, and filled in the gap between the end of the deck panels and the expansion joints. These pours were done one lane width at a time and then covered with a steel plate allowing traffic to pass over them.



Figure 16: getting ready for placement of concrete between precast sections and around new finger expansion joint.

Placing the Barrier and Silica Fume Concrete Overlay

Once the closure pours were in place, the permanent reinforced concrete barrier curb was poured by the slip form method. The barrier was started on the south end of the bridge even before all of the panels had been finished being placed on the north end just before Labor Day. The remaining rebar for the top of the barrier was tied during the day and the concrete poured at night.



Figure 17: Placing barrier curb by slipform method.

A 1 ½" thick silica fume modified concrete overlay was placed as the final wearing surface. This overlay would keep any water and salt from getting to the precast concrete panels, and would also even out the riding surface of the bridge. It was placed half a deck width at a time to allow one-lane of traffic to be open, while the concrete cured for 7 days. It was also placed at night to make sure the special silica fume concrete could be placed, finished and initially cured correctly. Silica fume is a very fine powder that is a waste product from making electronic grade silicone that is used in making computer chips. The silica fume powder (with particles as fine as cigarette smoke) is substituted for some of the cement in the concrete and fills all the pores in the mix, making it very dense and impervious to water and chloride ions in salt, which can deteriorate the concrete.



Figure 18: Uncovering the last of silica fume overlay placements.

Deck Replacement: Summary and Timeline

The first two precast deck sections were placed on the south end of the bridge on Sunday night June 27, 2004. (Thirty foot of old deck had been removed the week before and replaced with temporary bridge deck sections.) The last six precast panels were set on Tuesday August 31, 2004 to finish the job 2 nights earlier than allowed by the contract. The first section of the 1.5” thick silica fume overlay was placed on the southwest end of the bridge on the night of September 7, 2004. CC&G actually used 53 of 66 nights allowed in the contract to completely close the bridge from 7:00pm – 7:00am on Sunday through Thursday from Memorial Day to Labor Day. There was no disruption to two-way traffic on the bridge and approach roadways any time during the day, on weekends or holidays during the summer of 2004. There was almost no disruption to boat traffic since the channel was only closed at night when the barge that held the crane and deck panels had to be in the channel.

Placing the bridge deck overlay and approach pavements did require partial closings and one lane traffic, but on the new wider lanes, during September through November. However, unimpeded traffic was restored before November 30, 2004. This completed the project in less than one season with only a limited affect on busy vacation traffic. It has delivered a wider driving surface and a thicker deck, which should last for 30 to 40 years. This project would have taken at

least two construction seasons of one-way traffic on the bridge if the deck had been repaired in place using conventional methods.

Conclusions and Recommendations

Concerning the cost differential on this bridge using prefabricated sections, it was \$56.00/sq.ft. versus MoDOT's average cost of \$32/sq.ft. to \$40/sq.ft. for replacing a deck by conventional methods on a similar bridge. On this project however, being a very long bridge entirely over water and because of other circumstances it was considered the extra cost ultimately was very little. The low bid for this job was only about 9% higher than the original estimate that included stage construction. Jim Hartman the Project Manager explained, "We never really had a concrete difference in cost between doing the traditional method verses the precast panel method. I believe he (the design consultant) agrees but the thinking was that the comparison in cost would be a wash out. There were some things that maybe were going to make the precast method construction more costly than the traditional method such as the fact that this was a new, undone procedure in our area. Undoubtedly, the new procedure will become cheaper to construct as it is done more often. The significant difference in construction time between the two procedures made up for the difference in cost by greatly reducing the traffic control cost between the two."

MoDOT has learned a lot about designing and construction of a prefabricated bridge deck and should look for unique applications where this type of construction can speed up construction and reduce traffic congestion.

Appendix A

Work Plan

Research Work Plan

Date: 5/17/04

Project Number: RI04-027

Title:

Observe and Document Deck Replacement with Precast Reinforced Concrete Segments during Night Time Closures on Bridge A0941, Route 64, Hickory County, Project J8S0654

Research Agency: RDT, General Services – Photo Lab, Project Development, Construction & Materials

Principal Investigators: John D. Wenzlick, R&D Engineer- Principal Investigator
Mark Baumgartner – Video Photographer
Jim Hartman, Project Manager
Dennis Krenning, Resident Engineer

Objective:

RDT will observe and document the process of the first time tried in Missouri of nightly deck removal and replacement with precast full width panels with barrier attached. The bridge will be closed at 7:00 p.m. in the evening, as much original deck will be removed from the steel girders and replaced with as many 10 ft. long panels as can be installed, and the bridge re-opened to traffic by 7:00 a.m. the following morning. RDT will help coordinate so that construction operations are videotaped showing all steps of the segmental construction and assist the Photo Lab in putting together a video describing the project. Project Management, Bridge and the designers of the project HNTB will be consulted as needed to understand the design processes that were used in the project.

Additionally, if funding and equipment can be obtained, imbedded remotely monitored testing instruments will be installed as the deck sections are placed or before the final concrete overlay riding surface is placed on the bridge deck. These sensors will be non-destructive ways to test the performance of the deck in the future, for things such as corrosion, temperature and possibly strain in the concrete deck or the steel girders.

Background and Significance of Work:

This will be MoDOT's first full width with barriers attached segmental bridge deck construction replacement done by only closing the bridge 12 hours overnight and reopening every day.

Tracking this project to document successes and problems will be invaluable in future jobs like this in Missouri and also to other state DOT's. Both a written report and video presentation will be outcome from this project.

Also if remote test instruments are able to be installed the condition and the performance of the bridge deck can be non-destructively monitored for years to come.

Action Plan:

See “Procedures” below.

Literature Search: Planning and design of the project and bridge construction was done extensively by District 8 Project Management and by Central Office Bridge and HNTB. A literature search was conducted by RDT to find various non-destructive remote monitored instruments to try and monitor the completed bridge deck. The Photo Lab has extensive experience in producing video documents.

Method of Implementation: A report on the performance and constructability of the bridge deck replacement process will be made including cost/benefit data. A recommendation for further future use will also be made. This will be shared with the Bridge and Construction & Materials divisions and with other DOT's.

Anticipated Benefits: A timesaving was the reason the product was picked for this project. This study will verify the benefit of reducing construction time has in cost to MoDOT and road users cost savings to the motorist.

Research or Evaluation Period: It is estimated the study will last from May – December, 2004. The project completion date is November 30, 2004; field observation and test samples will be obtained during the construction project. Three months is needed to complete tests on sensors and to write a final report.

Potential Funding: \$ 160,000 of IBRC funds was transferred from a 2001 Stainless Steel Clad Reinforcement project that was never built because the materials couldn't be obtained. SPR and matching RDT funds will be used for reporting costs.

Procedure:

1. Pre-Bid and Pre-Construction meetings for the project were attended. A meeting to discuss the video filming will be held between the contractor, consultant and MoDOT personnel to discuss the videotaping and research needs during the construction project.
2. RDT will observe casting of panels, removal of the old deck and placement of new panels and observe night time construction process and will aid the Photo Lab in coordinating video taping of the whole process.
3. If instrumentation is obtained and installed, RDT will coordinate with designers and contractor a plan for installing the monitoring devices. RDT will purchase and install the remote monitored instruments.
4. RDT will observe placement of Silica Fume concrete overlay and offer any assistance they can and may take some additional materials samples for special testing (chloride content, permeability, electrical resistance, concrete strength, etc.)
5. RDT will assist the Photo Lab in producing a video of the construction process for

general distribution. RDT will produce a report to document the process for MoDOT and FHWA to fulfill reporting requirements for IBRC and also for technology transfer of this unique project and segmental construction process in general. A cost benefit and life cycle cost analysis will be included in this report.

6. If instrumentation is installed RDT will make at least yearly inspections for the next five years to gather data, analyze and report it and give an update on the bridge deck condition.

Staffing: RDT staff will include the PI an R&D engineer and an Intermediate R&D Assistant

Equipment: Photo Lab has all necessary video equipment
If available RDT will purchase sensors.

Budget:

FY 2005

PI – R&D Engineer	80 hrs.	\$3671.04
Staff – Inter. R&D Asst.	100 hrs.	\$3046.40
Video Photographer	100 hrs.	<u>\$2571.20</u>

\$ 9288.64

Meals & Lodging:

PI	6 nights	642
Staff	6 nights	642
Video Photographer	8 nights	<u>856</u>
		\$ 2140

Equipment;

Vehicle rental

Rate	Miles		
5 trips	0.33	190 (JC to Nemo round trip)	\$ 313.50

TOTAL BUDGET (w/o embedded sensors)

\$ 11,742

[If sensors installed FY2006 – FY2009]

[Staff – Inter. R&D Asst. 80 hrs. \$2437.12]

[If instrumented – return inspections; 4 trips \$250.80]

[Instrumentation - RFID system and temperature sensors \$3,000]

[- strain gauges, solar panel and corrosion sensors \$3,000]

[- VTI imbedded corrosion monitors (4 @ \$995)- \$4,000]

[Total Additional.....\$5,700 - \$12,700]